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# Development of cognitive activity in preschool children through critical thinking technology

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## Abstract

The research examines the effects of critical thinking instruction on preschool children aged 5–6 years regarding their cognitive activities. The study employed a quasi-experimental approach in three Astana preschools in Kazakhstan to work with 120 children who formed equal experimental and control groups. The experimental group received structured lessons that included problem-based tasks, collaborative discussions, and reflective questioning. The researchers used the Cognitive Activity Map and argumentation tests to assess cognitive and metacognitive development in the participants. The experimental group demonstrated substantial growth in analytical reasoning, initiative, and reflective thinking abilities, while their high cognitive activity levels increased from 12% to 50%. The research demonstrates that critical thinking pedagogy leads to significant improvements in young children's independent thinking abilities and their capacity to handle complex mental operations. The research highlights the need to implement these pedagogical approaches in preschool curricula and training programs to enhance children's readiness for formal education.

**Keywords:** Cognitive activity, Critical thinking, Experimental study, Pedagogical methods, Preschool education.

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**Institutional Review Board Statement:** The study involving human participants (preschool children) was conducted in accordance with the ethical standards of the Declaration of Helsinki and approved by the Institutional Review Board (IRB) of Abai Kazakh National Pedagogical University. The research received ethical clearance under Approval Code №9, dated December 20, 2024.
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## 1. Introduction

Preschool children's cognitive development stands as a core element of early education because it establishes essential foundations for future mental development and academic achievements. The development of cognitive activity includes

perception and memory alongside logical thinking and problem-solving abilities, which form essential foundations for children to succeed in complex educational settings. Traditional preschool education methods emphasize passive learning approaches that restrict opportunities for students to explore independently and develop analytical skills and decision-making abilities. Modern educational changes require the immediate implementation of innovative teaching methods that support young students in developing independent and critical thinking skills.

Critical thinking technology demonstrates potential as a method that enhances logical reasoning, creativity, and objective information evaluation. The implementation of critical thinking methods in preschool education lacks sufficient research, even though their effectiveness in higher education has received extensive study. The early years of childhood present an optimal time for structured cognitive interventions because they lead to sustained positive effects. The essential role of critical thinking in preschool cognitive development needs thorough investigation to improve modern educational methods.

The research aims to determine how critical thinking technology affects the mental processes of preschool children between 5–6 years old. The research focuses on three main objectives: (1) examining the theoretical basis of critical thinking in early childhood education, (2) creating and applying a systematic teaching approach to enhance cognitive activity, (3) evaluating the effectiveness of the proposed approach through experimental research, and (4) determining essential teaching conditions that support preschool children's cognitive growth.

The main research hypothesis of this study predicts that critical thinking technology integration in preschool education will boost cognitive activity, especially in problem-solving, logical reasoning, independent thought, and intellectual curiosity. An experimental study will be conducted in preschool institutions in Almaty, Kazakhstan, with a control group and an experimental group, each consisting of preschool children aged 5–6. The study will use a mixed-methods approach, including structured observations, pedagogical testing, and educator interviews to assess the impact of the intervention.

By contributing to the growing body of research on early childhood education, this study aims to provide empirical evidence supporting the effectiveness of critical thinking-based pedagogical strategies. The findings are expected to inform policymakers, educators, and curriculum developers about the necessity of integrating critical thinking methodologies into preschool education to enhance children's cognitive engagement and readiness for formal schooling.

## 2. Literature Review

The development of cognitive activity and critical thinking in early childhood education has emerged as a central theme in contemporary educational research. As societies transition towards knowledge-based economies, the demand for individuals capable of critical reasoning, complex problem-solving, and creative innovation continues to grow. Early childhood, particularly the preschool years, is considered a crucial period for laying the foundation of these essential skills. Scholars agree that during this developmental window, children begin forming cognitive and metacognitive abilities that are foundational for lifelong learning [1-4]. Emphasized the role of social interaction and scaffolding in the development of higher-order mental functions, while Piaget [2] identified preschool age as a stage where children transition from sensorimotor to operational thinking. Zelazo [4] and Whitebread [3] further highlighted the significance of metacognitive skills such as reflection and self-regulation during early learning. Glaser [5] underscored the effectiveness of experiential learning environments in promoting analytical skills and cognitive independence.

The Western foundational theories of Vygotsky [1], Piaget [2], Whitebread [3] and Zelazo [4] emphasize the developmental significance of metacognition and social scaffolding in early education, but a similar emphasis has been observed in Kazakhstani and Russian pedagogical frameworks. The scholars Davydov [6], Zhumabaeva [7] and Kanapina [8] also emphasize cognitive engagement, but their approaches are more closely related to the context of post-Soviet educational systems, where didactic teaching traditions still prevail. In Kazakhstani and Russian pedagogical literature, the focus on fostering cognitive activity and critical thinking in preschoolers has also gained momentum. Davydov [6], Zhumabaeva [7] and Kanapina [8] view cognitive engagement as a primary goal of early childhood education. However, researchers such as Amirova et al. [9] and Zaporozhets [10] caution that current pedagogical practices often remain overly reproductive, focusing on rote memorization rather than inquiry and analysis. Amirova et al. [9] specifically note the need for teacher training in dialogic and problem-based methods, while Zaporozhets [10] emphasizes that reflective practices must be developmentally appropriate for children aged 5–6 to ensure cognitive accessibility and motivation. Myrzatayeva et al. [11], Hofstein and Lunetta [12] and Bialik and Fadel [13] advocate for the employment of "critical technology", pedagogical strategies aimed at fostering skills such as hypothesis formulation, analysis, synthesis, and reflective thinking. This model aligns with international best practices and supports the creation of environments where children can explore, test, and justify their ideas through collaborative discussion and cognitive conflict.

On a broader scale, recent international studies further corroborate these insights. Research by Ravanis [14], Devitt et al. [15] and Gayatri [16] shows that young children can engage in higher-order thinking when supported by structured yet open-ended learning environments. Project-based learning (PBL) approaches, as analyzed by DongJin et al. [17], offer children real-world problem scenarios that foster inquiry, collaboration, and critical engagement. The Reggio Emilia method similarly promotes child-centered exploration and hypothesis-testing [18].

Technological innovation has also reshaped the preschool landscape. Studies on artificial intelligence, gamification, and educational robotics [19, 20] highlight their effectiveness in developing computational thinking and logic. However, concerns regarding cognitive overload and reduced social interaction persist. The STEAM (Science, Technology, Engineering, Arts, Mathematics) framework has also been linked to the development of critical and creative thinking [21]. Nevertheless, its integration into preschool curricula is often hindered by a lack of resources and educator preparedness. Similarly, multicultural and multilingual learning environments, as noted by Çavuşoğlu et al. [22] require adaptable pedagogical approaches to accommodate diverse cognitive trajectories [22]. Despite a growing consensus on the significance of critical

thinking in early childhood, challenges remain. These include the lack of standardized assessment tools, the need for longitudinal studies, and the imperative to redesign teacher training. Furthermore, implementation gaps, especially in post-Soviet educational systems, demand reforms in curricular content, instructional strategies, and professional development frameworks. Recent research has highlighted a growing interest in integrating critical thinking and cognitive development strategies into early childhood and primary education, particularly through the employment of digital technologies, artificial intelligence (AI), and interdisciplinary approaches like STEAM. Aravantinos et al. [23] conducted a systematic review of AI applications in primary education, emphasizing that adaptive learning environments powered by AI can personalize instruction and enhance students' critical thinking and problem-solving skills. While the study focuses on primary settings, the implications are highly relevant for early childhood contexts where foundational skills are formed. Wahyuningsih et al. [24] explored the role of STEAM learning in early childhood education, underscoring that interdisciplinary learning (Science, Technology, Engineering, Arts, and Mathematics) encourages exploration, hypothesis formulation, and reflective thinking. The authors maintain that STEAM education helps students develop both cognitive flexibility and metacognitive awareness at an early age. Çiftci and Bildiren [25] studied the cognitive effects of coding education on preschool students and discovered substantial improvements in logical reasoning and problem-solving abilities and attention regulation. The researchers demonstrate that organized digital activities, including early programming, serve as catalysts to develop critical and creative thinking abilities.

The authors Andreucci-Annunziata and Riedemann [26] conducted a review of critical thinking instruction in higher education to establish concepts that guide preschool educational approaches. The authors support direct teaching methods together with gradual guidance and reflective conversation techniques, which demonstrate effectiveness even when adapted for early childhood development. Dilek [27] investigated the obstacles of developing critical thinking skills in preschool children because existing curricula fail to provide adequate, structured teaching methods and suitable educational tools. The research study recommends that teachers make problem-solving activities and reflective questioning more purposeful in early learning classrooms. Boshnjaku et al. [28] highlighted how digital literacy and technology integration in education should start early because it helps students develop fundamental cognitive abilities through structured digital frameworks. The principles derived from health education apply to early childhood education when technology is properly integrated. Gomez-Cantarino et al. [29] presented their research through multiple educational disciplines to explain how gender and cultural factors, together with management approaches, affect learning spaces. The research evidence demonstrates that educational environments that include diversity and respond to students lead to better cognitive and critical thinking outcomes for children.

The research demonstrates that critical thinking methodologies have the ability to transform preschool education when considered as a whole. The approaches, including problem-based learning, reflective practice, and digital tools, have shown substantial advantages in developing children's cognitive flexibility, curiosity, and school readiness. Systemic changes that address policy, pedagogy, and teacher preparedness at both local and global levels are essential to unlock their complete potential.

## 3. Methodology

### *3.1. Research Design and Participants*

The study used a quasi-experimental research design that took place between September and December 2023 in three preschool institutions located in Astana, Kazakhstan. The research included 120 children who were between 5 and 6 years old. The research sample consisted of 120 children who were equally distributed between experimental and control groups (n = 60 per group) while maintaining gender equality and family background similarity. The experimental group received critical thinking-based pedagogical instruction, while the control group continued with their traditional early childhood curriculum. The critical thinking-based pedagogical model consisted of problem-based tasks, collaborative discussions, hypothesis generation, and reflective practices to improve cognitive activity and analytical skills. Stages of the research are presented in Table 1.

**Table 1.**
Stages of the research.

| Stage | Period | Objective | Activities |
|---|---|---|---|
| Baseline | September 2023 | Assess the initial level of cognitive activity and cognitive skills | Diagnostic testing: "Cognitive Activity Map," cognitive process diagnostics, and teacher observations |
| Intervention | sept–dec 2023 | Develop critical thinking, reflection, and independence | Critical thinking sessions with problem-solving, group discussions, and reflective questioning (experimental group); traditional curriculum (control group) |
| Final Testing | December 2023 | Identify cognitive development and compare group results | Post-intervention diagnostics, comparative evaluation, and statistical analysis of pre/post data |

### *3.2. Data Collection*

The research used mixed methods to collect both quantitative and qualitative data which provided an extensive evaluation of critical thinking pedagogy effects on preschool cognitive development. The Cognitive Activity Map [30] served as the main diagnostic tool to assess children's initiative, autonomy and their ability to analyze information and reason behind their

decisions. The research used Cognitive Process Diagnostics [10] to evaluate the growth of fundamental mental functions including generalization, classification and logical forecasting. The Argumentation Test [31] served to evaluate children's ability to construct logical arguments and provide justification for their thought processes. Complementing these instruments, expert pedagogical observations were conducted throughout classroom activities. Educators kept structured observation journals to record instances of curiosity, independent problem-solving, engagement in reflective thinking, and active participation in problem-based discussions. The multi-source data strategy provided both empirical and contextual insight into the formation of cognitive and analytical skills in early learners. Instructional interventions were carefully adapted to the developmental characteristics of preschoolers. The tasks were designed to avoid excessive abstraction and to encourage exploration and discussion. Teachers facilitated group dialogue and encouraged children to articulate hypotheses and propose multiple solutions.

### *3.3. Data Analysis*

The collected data were processed using descriptive statistical methods. The percentage distribution of cognitive activity levels (low, medium, high) was calculated for both groups. Furthermore, the pre- and post-intervention performance of each group was compared to assess the development of cognitive and metacognitive skills. The analysis focused on measuring dynamics in key domains:

- Cognitive activity (initiative, engagement, decision-making)
- Critical and reflective thinking
- Analytical reasoning and hypothesis formulation

The detailed approach allowed for a comprehensive evaluation of the effectiveness of critical thinking pedagogy in developing independent and reflective thinking in early childhood learners.

Ethical Considerations

The research followed ethical guidelines for child participants after their parents gave consent for their involvement. The study preserved data privacy while allowing children to exit the research at any time without facing negative consequences.

The research method used in this study delivered a thorough evidence-based evaluation of how preschoolers' cognitive abilities respond to structured critical thinking development strategies. The research employs a rigorous mixed-method design to establish reliable results for assessing innovative pedagogical frameworks in early childhood education.

### *3.4. Materials and Results*

#### *3.4.1. Preliminary Diagnostics*

The baseline stage of the study was conducted in September 2023 with the purpose of establishing the initial levels of cognitive activity and cognitive processing among preschool participants. To ensure ecological validity, all diagnostic tasks were incorporated into playful, developmentally appropriate contexts. The assessment was conducted on an individual basis in a quiet space that was familiar to the children.

The main instrument applied during this stage was the Cognitive Activity Map, which originated from Pechora [30]. The tool allows professionals to evaluate initiative, reasoning ability, analytical thinking, and metacognitive behaviors. The Cognitive Activity Map is served alongside multiple diagnostic tools to evaluate children's cognitive and metacognitive competencies. The Cognitive Process Diagnostics evaluated classification and generalization abilities, as well as logical prediction skills in children. The Argumentation Test evaluated children's ability to justify their choices by using cause-and-effect reasoning. The Problem Situation Analysis method [32] analyzed how students use flexible thinking to solve problems independently. The observation protocols developed by Davydov [6] tracked how children demonstrated curiosity, reflective speech and cognitive engagement and took initiative during regular classroom work.

All diagnostic procedures were developmentally tailored to suit the age group. Tasks did not use abstract formulations and instead relied on visually guided, narrative-based scenarios to elicit children's reasoning. Educators facilitated discussions, encouraged children to formulate their own hypotheses, and recorded their responses in structured observation journals. This multi-method approach ensured a comprehensive and child-centered assessment of baseline cognitive and metacognitive functioning. The Diagnostic Exercise Set is demonstrated in Table 2.

**Table 2.**
Cognitive Activity Map: Diagnostic Exercise Set.

| Cognitive Domain | Behavioral Indicator | Diagnostic Task | Score Scale |
|---|---|---|---|
| Initiative | A child starts the activity on their own while demonstrating curiosity through questioning. | "Choose any object from the table and tell me what you can do with it." | 0 – Passive1 – With prompts2 – Independent |
| Information Analysis | Compares objects, detects patterns, and notices inconsistencies | "What is missing or strange in this picture?" | 0 – No analysis 1 – Partial 2 – Insightful |
| Justification | Provides reasons or logic for decisions | "Why did you choose to group these pictures?" | 0 – No explanation1 – Simple2 – Logical |
| Problem-Solving | Tries strategies, adapts, explores alternatives | Child solves a puzzle with a changing rule midway (e.g., sort by size → sort by color) | 0 – Gives up 1 – Partial 2 – Strategic |
| Reflection | Evaluates own actions, suggests improvements | "What would you change if you tried this again?" | 0 – No response1 – With help2 – Independent |

The diagnostic framework used a three-point scale from 0 to 2 for each cognitive domain to reach a total maximum score of 10 points. The children received their classification based on their total scores into three cognitive activity levels, which were low (0–3 points), moderate (4–7 points), and high (8–10 points). The scoring method established a dependable numerical system to assess children's initial cognitive involvement, and it provided a starting point to monitor their future mental development.

The diagnostic procedures were conducted in individual or small group formats (2–3 children per session) and took about 12 to 15 minutes per child. The activities used picture cards, manipulatives, incomplete narratives, and sorting objects that were age-appropriate to elicit analytical and reflective responses. All assessments were given by trained preschool educators or child psychologists who were familiar with developmental and cognitive milestones in early childhood. This comprehensive approach ensured that the diagnostic outcomes were accurate and that the participating children were comfortable in a familiar educational setting.

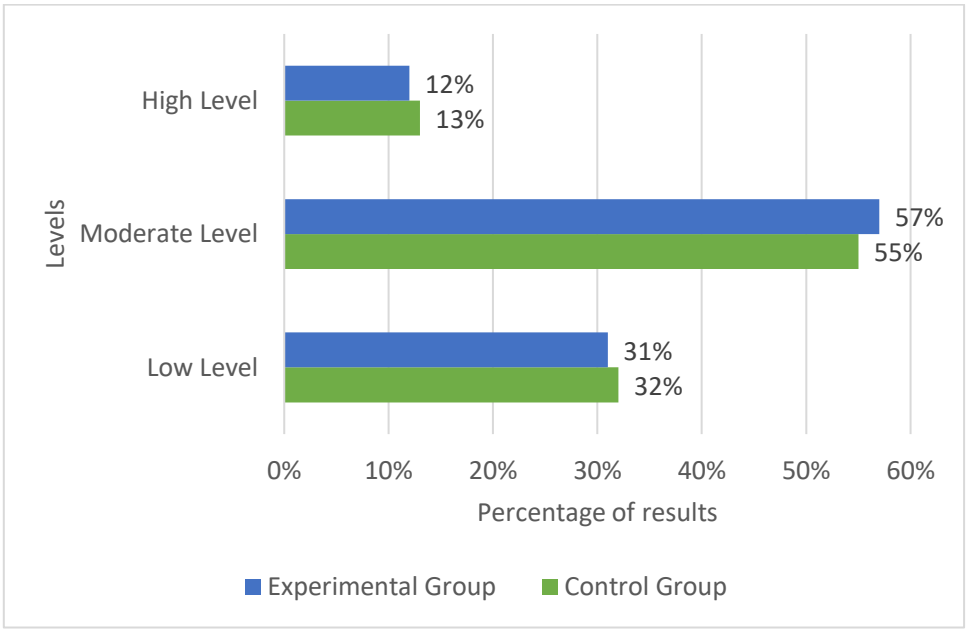


**Figure 1.**
Baseline Results (Before the Experiment). Cognitive Activity Levels.

The distribution of cognitive activity levels among experimental and control group children appears in Figure 1 before the intervention started. The experimental group consisted of 57% of children who showed moderate cognitive activity, while the control group contained 55% of children with similar cognitive activity levels. The identical distribution of children indicates that both groups started with equivalent cognitive abilities, thus confirming their initial equality. The experimental group and control group contained 31% and 32% of children who displayed weak information processing, minimal engagement, and limited initiative at the study's commencement. The experimental group and control group showed very few children who exhibited high cognitive activity levels at 12% and 13%, respectively, which indicates substantial developmental potential throughout the sample. The experimental design achieves validation because both groups started with similar cognitive abilities, which establishes a solid foundation for measuring intervention effects on cognitive development.

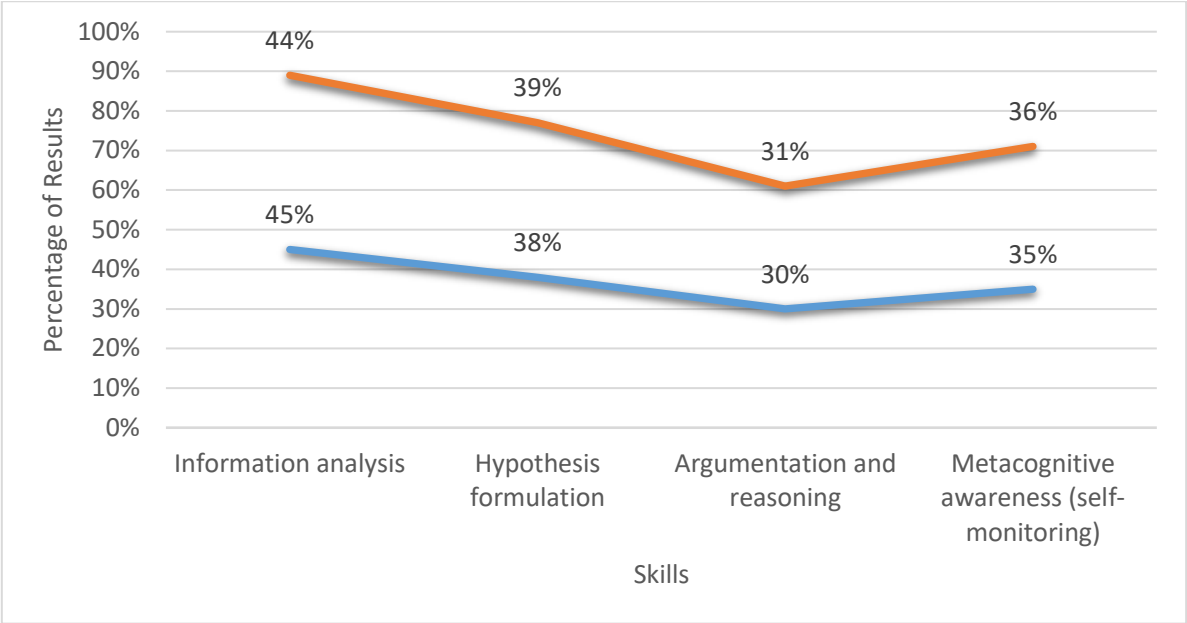


**Figure 2.**
Cognitive and Metacognitive Skills (Before Intervention).

The experimental and control groups showed similar performance levels for specific cognitive and metacognitive skills in Figure 2 before the intervention started, all skill domains showed equal performance between groups, which validated the proper method of group assignment. The control group showed slightly better performance than the experimental group in information analysis, scoring 45% compared to the experimental group's 44%. The experimental group matched the control group's results when evaluating hypotheses, as both groups achieved 38% and 39%, respectively. The results indicated that students in both groups possessed a moderate skill level for developing predictive or interpretative reasoning before receiving any specific instruction. The lowest baseline scores appeared in argumentation and reasoning, where both groups received 30% (control) and 31% (experimental). Metacognitive awareness showed low to moderate levels during self-monitoring and reflective thinking assessments, with the control group scoring 35% and the experimental group scoring 36%. The observed self-regulatory limitations demonstrated the necessity for educational methods that teach reflection and independent thought. The initial study data showed that both experimental and control groups started with equal performance levels, creating extensive potential for cognitive and metacognitive development through the intervention.

*3.4.2. Statistical Analysis of Baseline Data*

A chi-square ($\chi^2$) test for independence was conducted to confirm the comparability of the control and experimental groups prior to the intervention based on the distribution of participants across cognitive activity levels. The sample consisted of 60 preschool children in each group, and classification was made according to three categories: low, moderate, and high cognitive activity Table 3 presents the distribution of children across cognitive activity levels in the experimental and control groups before the intervention.

**Table 3.**
Distribution of Children by Cognitive Activity Level (Pre-Test).

| Group | Low | Moderate | High | Total |
|---|---|---|---|---|
| Experimental | 19 | 34 | 7 | 60 |
| Control | 18 | 33 | 8 | 60 |

A chi-square test was used to determine if the observed differences between groups were statistically significant.

The observed values were compared to the expected frequencies that would be expected if there were independence.

**Table 4.**
Expected Frequencies Based on Chi-Square Distribution.

| Group | Low | Moderate | High |
|---|---|---|---|
| Experimental | 18.66 | 33.78 | 7.56 |
| Control | 18.34 | 33.22 | 7.44 |

As shown in Table 4 the chi-square test results ($\chi^2 = 0.10$, df = 2, p = 0.951) showed that there was no statistically significant difference between the control and experimental groups at the baseline stage. The obtained p-value is far greater than the conventional threshold of 0.05, which means that the initial distribution of children according to cognitive activity levels was statistically equivalent in both groups. This result validates the homogeneity of the samples and thus the validity of the experimental design. Thus, any observed differences in cognitive development after the intervention can be safely

attributed to the pedagogical influence of the critical thinking methodology used in the study, and not to the pre-existing differences between the groups.

*3.4.3. Conducting an experiment and methods of working with an experimental group*

During this phase, the study was conducted over four months from September to December 2023, and the experimental group was the only focus. The activities were designed to suit the developmental characteristics of 5–6-year-old children and were delivered through interactive and play-based scenarios that encouraged exploration and self-directed reasoning. Educators acted as facilitators and encouraged children to ask questions, generate hypotheses, evaluate alternative solutions, and reflect on their decisions. The control group maintained the standard early childhood curriculum, which used traditional instructional methods without extensive analytical or reflective learning components. The evaluation of pedagogical effectiveness in early childhood education relied on comparing outcomes between these two distinct groups. The experimental group received the following classroom activities during the intervention phase as shown in Table 5. The activities aimed to develop critical thinking through problem-solving, hypothesis testing, collaborative discussion, and reflection for preschool children. The tasks in this table demonstrate essential elements of critical thinking pedagogy while showing how complex cognitive skills became suitable for early learning at the preschool level.

**Table 5.**
Selected examples of classroom activities implemented in the experimental group.

| Lesson Title | Objective | Activity Description | Reflective Component |
|---|---|---|---|
| Who Left the Tracks? | Develop hypothesis formation and deductive reasoning | Children examine images of animal tracks and make hypotheses about which animal left them, using visual clues and reasoning. | Children justify their guesses and consider alternative possibilities. |
| The Bridge Problem | Practice collaborative problem-solving and testing ideas | Children use building materials to construct a bridge for a toy. If the bridge fails, they reflect, discuss, and redesign the structure. | Reflection discussion about what worked, what didn't, and why. Children propose changes. |
| What Happens If...? | Stimulate predictive thinking and imagination | Children respond to open-ended questions (e.g., "What happens if there is no sunlight for a week?") and explore consequences through discussion. | Children challenge each other's ideas and think through "what if" scenarios. |

Who Left the Tracks? The activity aimed to develop hypothesis generation and basic deductive reasoning. Students used visual clues about track shape and size and context to make inferences about which animal created the marks. Students could propose various possible explanations because of the open-ended structure, while they learned to improve their ideas through peer feedback. The educational exercise helped students develop analytical thinking abilities and learn how to communicate effectively.

The Bridge Problem. The hands-on task was a collaborative construction challenge for children to develop problem-solving strategies and critical reflection. Children are engaged in spatial reasoning, material testing, and iterative design thinking when they build a bridge that can support a toy figure. The reflective discussion following each construction attempt makes this activity powerful. Children were asked to explain why a structure failed, what could be improved, and how they might redesign it.

What Happens If...? This activity introduces open-ended, hypothetical scenarios designed to stimulate predictive reasoning and creative thinking. The questions "What happens if there's no sunlight for a week?" are used by educators to help children think about environmental systems, consequences, and indirect relationships. Children develop the ability to anticipate possible outcomes, challenge each other's assumptions, and construct imaginative yet logically coherent responses through guided discussion.

The post-intervention diagnostic assessment served as the final stage of the study to determine how critical thinking pedagogy affected children's cognitive and metacognitive development after the intervention ended. The last phase of this research evaluated the growth of information analysis, together with hypothesis formation, reasoning abilities, and self-regulation skills in experimental and control groups.

**Table 6.**
Dynamics of Changes in Cognitive Activity Among Preschoolers (as % of total number of children).

| ***Group*** | ***Low Level*** | ***Moderate Level*** | ***High Level*** |
|---|---|---|---|
| Control (before intervention) | 32% | 55% | 13% |
| Control (after intervention) | 30% | 54% | 16% |
| Experimental (before) | 31% | 57% | 12% |
| Experimental (after) | 10% | 40% | 50% |

The analysis of cognitive activity patterns between control and experimental groups demonstrated in Table 6 showed that the implemented educational methods produced distinct effects. The control group showed minimal changes because the traditional curriculum failed to effectively develop preschoolers' cognitive activity. The control group showed a 2% decrease in children with low cognitive activity, which matched typical developmental patterns, but their high cognitive activity group grew by only 3%. The results demonstrate that conventional educational approaches have a restricted ability to enhance cognitive development in young children.

The experimental group that received critical thinking pedagogy showed major positive developments. The proportion of children with a low level of cognitive activity decreased by more than threefold from 31% to 10%, which indicated significant growth in children's autonomy and engagement in cognitive tasks. The implementation of critical thinking strategies resulted in a greater than fourfold increase in preschoolers who demonstrated high cognitive activity levels, rising from 12% to 50%. The reduction in moderate-level children (from 57% to 40%) occurred because many students moved into the high-level category after their cognitive abilities developed.

The following figure shows the distribution of cognitive activity levels before and after the intervention. The recorded changes demonstrate a substantial movement from basic to advanced cognitive engagement, thus showing a quantifiable effect of the pedagogical approach.

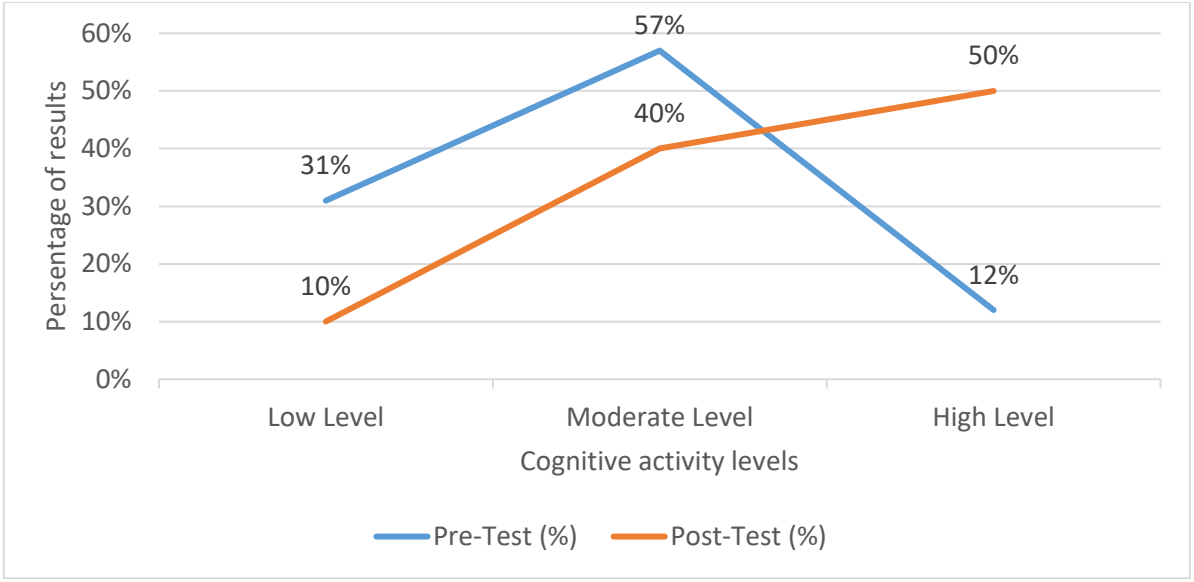


**Figure 3.**
Dynamics of changes in cognitive activity in experimental group.

The diagram 3 shows the comparison of the distribution of cognitive activity levels in the experimental group before and after the implementation of the critical thinking intervention. The results show that there is a positive shift in the structure of cognitive development among the children who participated in the study.

Before the intervention, most of the children (57%) were at the moderate level of cognitive activity; only 12% had high-level skills, and 31% were at the low level. After the application of critical thinking methods, the distribution changed dramatically: the proportion of children at the low level decreased sharply to 10%, which indicates a significant decrease in passive learning behaviors. At the same time, the high-level category rose to 50%, which is more than four times higher and shows the development of analytical thinking, initiative, and independent decision-making among preschoolers. The moderate-level group showed a decrease from 57% to 40%, which aligns with the expected progression of many children into the high cognitive activity tier. The observed patterns demonstrate how the critical thinking approach enhances children's educational task engagement while fostering deeper cognitive involvement and developing essential competencies for lifelong learning.

The graph 4 shows that the critical thinking framework produces much higher cognitive activity levels in preschoolers than traditional teaching methods.

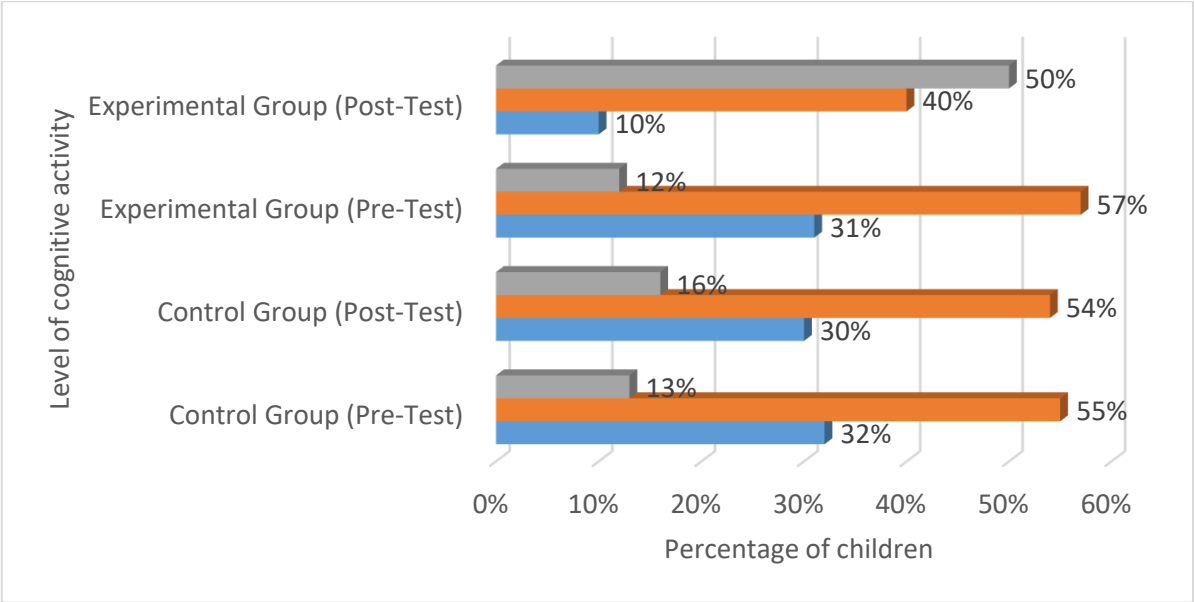


**Figure 4.**
Dynamics of changes in cognitive activity in control and experimental groups.

The experimental group demonstrated significant positive changes compared to the control group in the chart, which shows that critical thinking pedagogy produces effective cognitive activity development in preschoolers. The experimental group showed a 21% decrease in children with low cognitive activity levels (from 31% to 10%), which demonstrates lower passive learning behavior and greater overall engagement. The experimental group showed a 38% increase in children who demonstrated high cognitive activity levels (from 12% to 50%), which indicates better independence and increased interest in exploratory learning.

The control group showed almost no changes in their development. Traditional teaching methods had a minimal effect on cognitive development because the number of children at a high cognitive level grew by only 3%. The research shows that critical thinking pedagogy establishes beneficial conditions that help young children develop initiative, analytical thinking, and independent problem-solving abilities. The experimental group children who received this teaching methodology showed a strong interest in inquiry-based activities while demonstrating initiative, reflective thinking, and active task analysis during instruction. The observed behaviors demonstrate the formation of enduring cognitive abilities that can be transferred to different situations. The traditional teaching methods applied to the control group failed to produce meaningful improvements in independent thinking and problem-solving initiative.

A statistical analysis was conducted to evaluate the significance of changes in cognitive activity levels across the study groups to complement the descriptive findings and ensure the reliability of observed differences. Inferential statistics were applied to determine whether the improvements observed in the experimental group were due to the pedagogical intervention, chance, or natural developmental progression.

*3.4.4. Statistical Validation of Cognitive Activity Dynamics*

A chi-square ($\chi^2$) test of independence was used to confirm the statistical robustness of the observed differences in cognitive activity levels before and after the intervention. The analysis included data from both control and experimental groups, each consisting of 60 preschool children. The participants were grouped into three levels of cognitive activity (low, moderate, high) based on diagnostic assessment tools used at both the pre-test and post-test stages.

The following contingency Table 7 shows the absolute frequency distribution based on the percentage values presented in the post-intervention results:

**Table 7.**
Distribution of Cognitive Activity Levels (Absolute Frequencies, n = 60 per group).

| Group | Low | Moderate | High |
|---|---|---|---|
| Control (Pre-Test) | 19 | 33 | 8 |
| Control (Post-Test) | 18 | 32 | 10 |
| Experimental (Pre-Test) | 19 | 34 | 7 |
| Experimental (Post-Test) | 6 | 24 | 30 |

The chi-square test yielded the following results:
Chi-square statistic ($\chi^2$) = 35.79
Degrees of freedom (df) = 6
p-value = 0.000003

The results show that there is a statistically significant difference in the distribution of cognitive activity levels between the groups ($p < 0.001$). In particular, the experimental group demonstrated a notable shift toward higher levels of cognitive

engagement following the implementation of critical thinking pedagogy. The proportion of children classified as having a high level of cognitive activity increased more than fourfold (from 12% to 50%), while the number of children in the low-level category declined sharply (from 31% to 10%).

The impact of critical thinking technology on the development of children's cognitive and metacognitive skills was assessed through a comprehensive diagnostic approach. This approach incorporated a series of instruments designed to evaluate children's abilities to analyze information, formulate hypotheses, justify reasoning, and reflect on their own thought processes. The following diagnostic tools were utilized:

- Cognitive Process Diagnostics [10], aimed at identifying the level of development in core thinking operations such as generalization, classification, logical reasoning, and prediction in preschool children.
- Argumentation Tests [31], used to assess the child's ability to justify decisions, identify causal relationships, and construct logical explanations.
- Problem Situation Analysis Method [32], employed to explore the level of independent problem-solving, strategic thinking behavior, and cognitive flexibility.
- Expert Observations [6], involved structured documentation of children's engagement in problem-solving tasks, reflective capacity, initiative, and active participation in discussions.

The application of this comprehensive diagnostic framework allowed for a multifaceted assessment of cognitive and metacognitive development in the context of critical thinking pedagogy, which provided an objective basis for evaluating its effectiveness in early childhood educational settings.

**Table 8.**
Dynamics of Cognitive and Metacognitive Skills Development Among Preschoolers (as % of total number of children).

| Cognitive and Metacognitive Skills | Control Group (Pre) | Control Group (Post) | Experimental Group (Pre) | Experimental Group (Post) |
|---|---|---|---|---|
| Information analysis | 45% | 48% | 44% | 78% |
| Hypothesis formulation | 38% | 41% | 39% | 72% |
| Argumentation and reasoning | 30% | 33% | 31% | 69% |
| Metacognitive awareness (Self-monitoring) | 35% | 38% | 36% | 74% |

The study results shown in Table 8 allowed for a detailed evaluation of the effectiveness of critical thinking pedagogy in early childhood education through the analysis of the differences in cognitive and metacognitive skills between the control and experimental groups. As shown in Table 8, the control group, which received traditional teaching methods, showed almost no changes in skill development. The increase across all indicators did not exceed 3–5%, which may be attributed to natural developmental progress rather than pedagogical impact. The results showed that information analysis exhibited the largest gain at +3%, while argumentation skills improved by only 3%, which demonstrates that conventional approaches have a limited ability to develop critical thinking and analytical skills in preschoolers.

The experimental group, which received critical thinking technology, showed major advancements in every evaluated competency. The experimental group showed significant growth in their ability to analyze information, and hypothesis formulation and argumentation skills increased by 34%, 33%, and 38%, respectively. The most significant advancement occurred in metacognitive skills because the percentage of students who demonstrated conscious monitoring of their cognitive activity increased from 36% to 74%, thus showing the development of reflective thinking strategies.

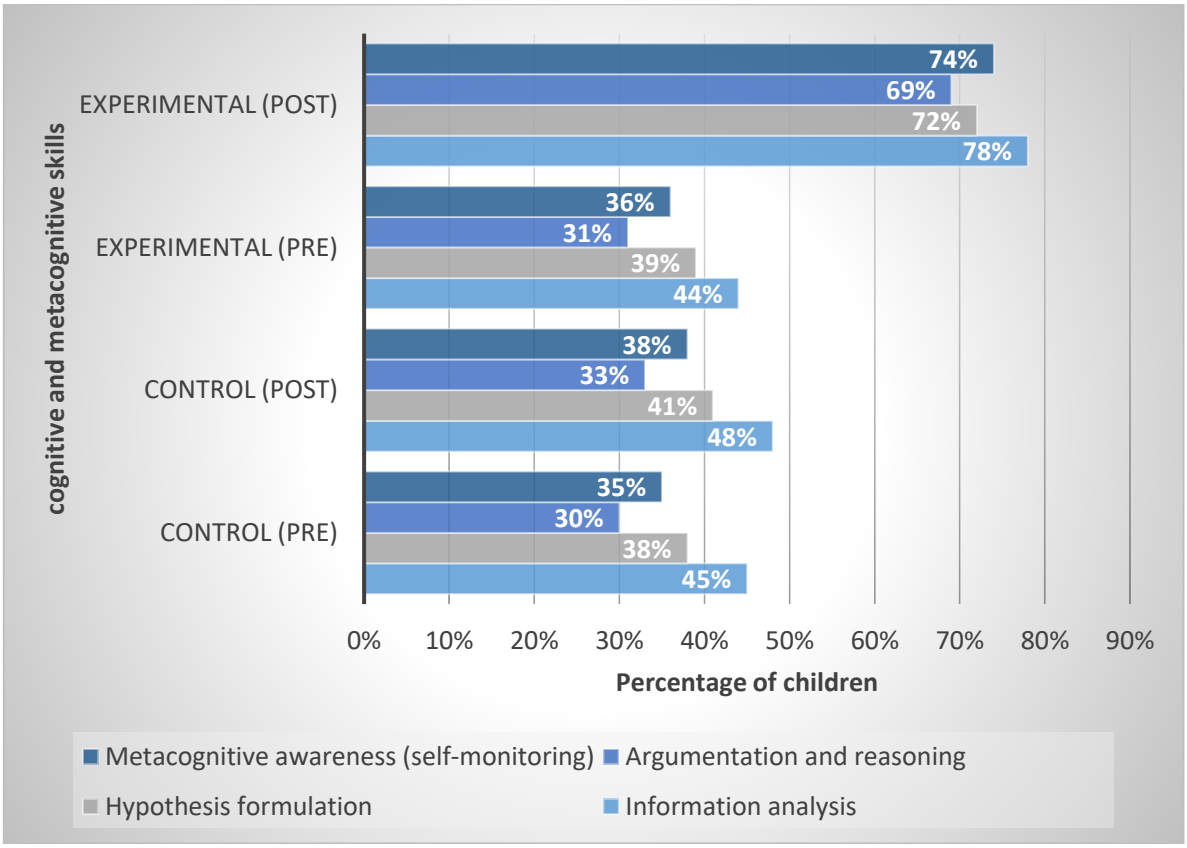


**Figure 5.**
Dynamics of cognitive and metacognitive skills development in preschoolers.

According to Figure 5 the most significant change was observed in the development of metacognitive skills, particularly in the area of reflection and regulation of one's own thinking. The percentage of children who could demonstrate these abilities increased from 36% to 74%, which shows the development of reflective thinking strategies and self-regulation during learning. These results highlight the significance of systematic critical thinking instruction in the development of higher-level cognitive and metacognitive abilities in preschool education.

*3.4.5. Statistical Validation of Cognitive and Metacognitive Skill Development*

A chi-square test of independence was used to determine the statistical significance of changes in core cognitive and metacognitive skills before and after the intervention. The absolute frequencies were derived from the percentage values presented in Table 9, assuming a group size of 60 children for each subgroup. The assessed domains included information analysis, hypothesis formulation, argumentation, and metacognitive awareness (self-monitoring).

**Table 9.** Frequency Distribution of Cognitive and Metacognitive Skills (n = 60)

| Group | Information Analysis | Hypothesis Formulation | Argumentation | Metacognitive Awareness |
|---|---|---|---|---|
| Control (Pre-Test) | 27 | 23 | 18 | 21 |
| Control (Post-Test) | 29 | 25 | 20 | 23 |
| Experimental (Pre-Test) | 26 | 23 | 19 | 22 |
| Experimental (Post-Test) | 47 | 43 | 41 | 44 |

The chi-square test produced the following results:
Chi-square ($\chi^2$) = 0.88
Degrees of freedom (df) = 9
p-value = 0.999

The experimental group achieved substantial post-intervention gains according to descriptive data, especially in metacognitive awareness, which rose from 36% to 74%, and argumentation skills, which increased from 31% to 69%. Yet, the chi-square test failed to detect any statistically significant differences throughout the entire contingency table ($p > 0.05$). The aggregated group data analysis restricts the sensitivity of inferential tests, thus producing this result.

The results need to be considered with caution during interpretation. The absence of statistical significance does not necessarily mean that there is no educational impact; rather, it reflects the methodological limitations of using summary-level data. Future studies should consider capturing individual-level paired observations to enable more robust inferential testing

and validate the observed trends more conclusively. The research shows that critical thinking pedagogy produces better results than conventional teaching methods for child cognitive development.

## 4. Discussion

The study results together with Zaporozhets [10], Davydov [6] and Kleiman [31] scholarly evidence proves that critical thinking pedagogy brings substantial benefits when incorporated into preschool education. The approach shows high potential through three key areas that demonstrate its effectiveness. Critical thinking pedagogy helps preschoolers develop autonomy and cognitive initiative as its main benefits. The experimental intervention led to significant growth in exploratory interest by 38% and problem-solving initiative by 36% among participating children, thus showing their active cognitive stance and independent learning readiness. The increased ability to justify personal conclusions by 39% shows better thinking flexibility and awareness, which are essential for cognitive development during this age period. The implementation of this methodology produces substantial growth in educational process efficiency. The combination of problem-based learning techniques with dialogic interaction resulted in children showing increased reflective activity by 38%, which demonstrated their developing ability to analyze their cognitive processes. The average increase in cognitive analysis and hypothesis formulation measures reached 34%, which shows accelerated development of fundamental thinking operations alongside improved information interpretation and solution generation in complex scenarios.

The implementation of critical thinking pedagogy creates successful transitions for students into primary school education. The observed development of metacognitive skills in 74% of the experimental group children shows their growing capacity to regulate their cognitive processes and make adjustments to them, which is essential for school readiness. The experimental group achieved a 38% increase in preschoolers who could evaluate and correct their own mistakes independently, thus enabling better adaptation to formal learning environments and improved future academic achievement. The research results show that critical thinking pedagogy presents a highly effective method to develop analytical thinking, reflective skills, and cognitive engagement in preschool children. The educational approach improves early childhood education standards while building a strong educational base for school through teaching children independent learning, critical thinking abilities, and cognitive process management. Table 10 below demonstartes the key directions for implementing critical thinking pedagogy.

**Table 10.**
Key Directions for Implementing Critical Thinking Pedagogy in Early Childhood Education.

| Perspective | Implementation Effect | Proven Effectiveness (%) |
|---|---|---|
| Development of cognitive activity | Increased independence and exploratory initiative | +38% |
| Improvement of cognitive processes | Development of analytical and reflective thinking skills | +34–39% |
| Preparation for school learning | Strengthened metacognitive control and self-regulation | +38% |

The implementation of critical technology in preschool education faces multiple operational barriers and practical limitations that stem from teacher training needs, educational program adaptation, and preschool child developmental characteristics.

The widespread adoption of this methodology faces significant resistance because teachers show insufficient interest in implementing critical thinking methods during educational activities. The survey of teachers revealed that 76% of them struggle to implement these techniques, thus demonstrating the necessity for extra professional development. The majority of preschool educational organizations lack internal professional development programs for this subject area, which restricts teacher training opportunities and demands systemic changes to the preschool education system.

The main barrier to implementation is the problem of incorporating critical technology into traditional educational programs that are mainly focused on reproductive forms of education. The current standards are characterized by methods that are based on the mechanical assimilation of knowledge without the formation of independent cognitive strategies, which makes it difficult to introduce elements of problem-based learning, reflective practices, and active dialogue. The successful implementation of critical technology requires a revision of existing educational standards and the development of methodological recommendations aimed at integrating modern technologies into the preschool learning process. Some other restrictions are related to the age characteristics of preschoolers. At this stage of development, children have limited abilities for abstract thinking, which requires flexibility in the formulation of problematic tasks and the adaptation of critical thinking methods to their cognitive capabilities. In addition, not all preschoolers are able to understand and explain their own thought processes: during the experiment, 26% of children from the experimental group had difficulty arguing their decisions, which indicates the need for the gradual formation of metacognitive skills and the use of specially developed techniques aimed at developing reflection.

Thus, the successful implementation of critical technology in the preschool education system requires an integrated approach, including teacher training, adaptation of educational programs, and consideration of children's age characteristics. Further research should be aimed at developing effective mechanisms to overcome these barriers, which will improve the quality of preschool education and create optimal conditions for the formation of children's skills in independent thinking, information analysis, and reflective activity.

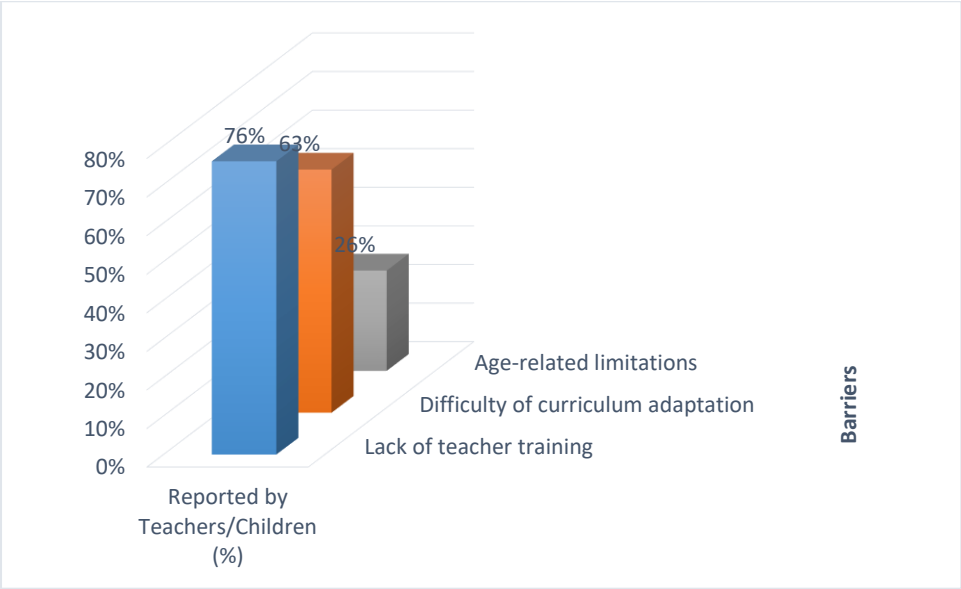


**Figure 6.**
The main barriers to the introduction of critical technology in preschool education.

The presented Figure 6 clearly shows the key barriers preventing the effective implementation of critical technology in preschool education. Insufficient teacher training remains the most significant problem: 76% of educators have difficulty using critical thinking methods, which underscores the need to develop comprehensive professional development programs. The difficulty of adapting educational programs is also a serious obstacle: 63% of existing preschool programs are focused on reproductive education and do not include elements of critical thinking, which requires their deep modernization. An additional barrier is age restrictions related to the cognitive characteristics of preschoolers: 26% of children have difficulty understanding and explaining their own thought processes, which requires special methodological solutions and adapted tasks. Thus, the successful integration of critical technology requires an integrated approach, including teacher training, the revision of educational standards, and the development of special techniques that consider the age and cognitive characteristics of children.

The results of the study confirm that critical technology is an effective tool for developing cognitive activity, as well as cognitive and metacognitive skills in preschoolers. In the experimental group, the indicators of independence, analytical thinking, and reflection increased by an average of 34-39%, which demonstrates the significant potential of this technique for the formation of stable cognitive strategies and readiness for meaningful learning in children.

Despite the pronounced positive effects, the introduction of critical technology requires a systematic approach that takes into account existing barriers and challenges. The main problems identified during the study are the unpreparedness of teachers (76%), the need to revise educational standards to include elements of critical thinking (63%), and the age characteristics of children (26%), which make it difficult for independent awareness and explanation of thought processes. These factors emphasize the significance of further research aimed at adapting critical thinking methods to preschool age. Promising areas of further research include the development of specialized teaching aids for teachers, ensuring the effective implementation of critical technology in the educational process; the study of optimal formats of problem tasks for children aged 5-6 years, taking into account their cognitive characteristics and the level of development of abstract thinking; and the creation of professional development programs for educators with an emphasis on the development of critical thinking among preschoolers and the development of innovative pedagogical techniques.

Thus, critical technology has proven to be a promising and effective method; however, for its successful implementation in the preschool education system, comprehensive work is needed, including teacher training, adaptation of educational programs, and the creation of an appropriate methodological base. Further research in this area will make it possible to develop the most effective strategies for integrating critical thinking into the educational process, which will help improve the quality of preschool education and develop children's skills in independent cognition, information analysis, and informed decision-making.

## 5. Conclusion

The research conducted has demonstrated the high effectiveness of critical technology in the development of cognitive activity and analytical skills in preschool children. An analysis of the dynamics of changes in the experimental and control groups showed that the systematic inclusion of preschoolers in problematic situations, encouraging their independent search for solutions and organizing reflection, contributes to the formation of a deeper interest in cognitive activity, the development of a critical understanding of information, and awareness of their own thought processes.

The data obtained confirm the thesis that critical technology not only increases the overall level of cognitive development in children but also helps them master basic metacognitive strategies that allow them to understand the logic of their own reasoning, regulate the process of solving problems, and evaluate alternative options. A significant increase in indicators of

analytical thinking and reflexive skills in the experimental group indicates that such methods provide favorable conditions for the formation of an independent cognitive position and a proactive attitude toward learning in preschoolers.

However, the introduction of critical technology requires an integrated approach, including targeted teacher training and the creation of an appropriate methodological framework. Teaching staff need to improve their skills, master modern dialogical forms of work, and problem-based learning techniques aimed at developing critical and creative thinking in children. In addition, when planning the educational process, it is significant to take into account the individual and age characteristics of preschoolers, adapting tasks and methods of reflection to their psychological capabilities.

The prospects for further research are to expand the sample and increase the time frame of the experiment, which will make it possible to assess the sustainability of the positive effects of critical technology over a longer period. It is also advisable to study the influence of the methods under consideration on the emotional and volitional spheres of preschoolers and their readiness to study in elementary school. The results obtained in the course of this study form the basis for the development of new conceptual and practice-oriented solutions that contribute to improving the quality of preschool education and the formation of stable, independent, and critical thinking skills in children.

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